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ABSTRACT

This paper reports an investigation of gender-indicating acoustic properties of the vocalizations of 73 six- and seven-year-old speakers. Tape recorded samples of these children's isolated vowel and sentence productions were presented in four listening sessions. One hundred and sixteen young adult (age 17-24) female listeners made gender judgments based on four utterance types: phonated and whispered/ae/vowels, and a normally-spoken and a monotonously-spoken nine-syllable sentence. Data were analyzed by means of a three-variable (utterance type, speaker sex, and listener trial) partially-repeated-measures analysis of variance. Among the findings, analysis indicated significant main effects for utterance type and speaker sex, and a significant interaction between these two variables. The presence of monotonicity increased the likelihood that a child would be assigned to the male category, but high listener accuracy in both sentence conditions suggests that intonation patterns did not provide primary cues to sexual identity.
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Sexual Characteristics
of
Preadolescent Children's Voices

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A paper presented at the American Speech and Hearing Association Convention, Chicago, Illinois, November, 1977. This paper is based on a doctoral dissertation completed by Suzanne Bennett at Purdue University, 1977.

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As part of contemporary interest in the speaker identification process, investigators have sought to specify sex-bearing attributes of the voice. Several researchers have shown that sexual characteristics are prominent in the voices of preadolescent children. This has been demonstrated among speakers 4-14 years of age who were producing utterances ranging from isolated vowels and CV syllables to spontaneous connected utterances. Yet, we have only cursory information about the acoustic factors which define maleness and femaleness in speakers who have not yet reached pubescence.

Several years ago Weinberg and Bennett showed that there was extensive overlap in the average fundamental frequencies and fo ranges of the five and six year old children whose sex was correctly identified. More recently, Ingrisano and Thompson found that mean fundamental frequency, relative amplitude, and syllable rate characteristics were generally similar for the seven 4 and 5 year old speakers who were identified with better than 90% accuracy. Although Ingrisano and Thompson noted that the four children categorized male had lower resonance frequencies than the three children categorized female, they suggested a cautious interpretation of their data because of a high number of missing measurements. Finally, these authors suggested that there were differences in the intonation contours of their seven subjects. The exact nature of these differences was not specified.

Sachs and colleagues (1973) examined the mean fundamental frequency and formant frequencies of isolated vowels produced by 18 boys and girls ranging in age from 4-14 years. They noted that the mean fo of boys was significantly higher than that of girls, a finding which conflicts with that of Weinberg and Bennett and Ingrisano and Thompson. Sachs et al. also found that the frequencies of certain resonances of /i/ and /u/ vowels were lower for speakers perceived as males. Yet, no significant sexual differences were observed for these children's /a/ vowels. These acoustic data are also complicated by the fact that some of Sachs's subjects were as old as 14 years, and as a result, may have already entered the pubertal stage of development.

Two additional findings emerged from the Sachs study. First, the accuracy of listener judgments was significantly higher for sentences as compared to isolated vowels. In addition, listener accuracy decreased when judgments were based on backward-played sentences. As Sachs suggested, the fact that listener accuracy was higher for sentences as compared to isolated vowels may only mean that listeners had more phonetic material upon which to base a judgment. Hence, no firm conclusions can be drawn about the role these children's intonation patterns played in the recognition process. Similarly, since several attributes of the speech signal are changed in a backward played condition, we cannot say with certainty that a disturbance in intonation patterns exerted a detrimental influence on listener judgments.

The purpose of this project was to explore the prominence of sexual characteristics in 73 six and seven year old speakers in order to gather information about acoustic properties which guide the perception of maleness and femaleness. In this work, listener judgments were based on four different utterance types: phonated and whispered /ae/ vowels, a nine-syllable sentence spoken in a normal fashion, and the same sentence spoken in a monotonous fashion--that is, with minimal variations in fundamental frequency. It was predicted that differences in vocal tract resonance characteristics reflecting sexual differences in vocal tract size and/or certain articulatory behaviors would provide the

major cues about child sex when judgments are based on isolated vowels and that phonatory cues (e.g. Ave fo characteristics) do not provide critically relevant perceptual information. If these predictions are true, the accuracy of listener judgments for phonated and whispered vowels should be comparable.

With respect to the sentence material, it was predicted that cues derived from the intonation contours of boys and girls would provide relevant information about sexual identity. If this is indeed the case, the rates of identification observed for the monotone condition should be significantly lower than those observed for sentences which were normally intoned.

Tape recorded samples of these children's isolated vowel and sentence productions were presented in four listening sessions. Twenty-nine different listeners were used in each condition. To provide an estimate of listener reliability, each speaker's sample appeared twice in random order in each of the utterance conditions. The listeners' task was to indicate whether the speaker producing the sample was a boy or a girl. One-hundred-sixteen young adult females ranging in age from 17-24 years served as listeners. All judges were naive with respect to judging speech samples.

Perceptual data were analyzed by means of a three-factor partially repeated measures analysis of variance. This procedure permitted the assessment of differences in listener perception as a function of three main effects: utterance type, speaker sex, and listener trial.

The major results of the ANOVA showed significant main effects for utterance type and speaker sex, and a significant interaction between these two variables. The main effect for listener trial and three factor interaction did not reach significance, indicating that listeners responded similarly to the first and second presentation of each child in each utterance condition.

Post hoc tests were used to probe the source of the significant speaker sex utterance type interaction. In essence, these tests provided a means for determining whether there were significant differences for whispered versus phonated vowels and normally spoken versus monotone sentences.

The major results of these analyses showed that the rates of accuracy for the phonated and whispered vowels were not significantly different for either boys or girls.

SLIDE 1

As can be seen in the left portion of this slide, the rates of accuracy for whispered and phonated vowels produced by boys were markedly similar--67% for whispered vowels and 68% for phonated vowels. The right portion of this slide shows the data for females. Here again, we see a marked similarity for the two vowel conditions--65% correct for the whispered vowels and 63% for the phonated vowels. Viewed together, these results were interpreted to suggest that vocal tract resonance cues reflecting sexual differences in vocal tract size and/or sex specific phonetic variations in these /ae/ vowels provided relevant information about the sex of these children. Stated differently, the addition of vibratory source information in the phonated vowel condition failed to bring about a systematic increase in the accuracy of listener judgments.

SLIDE OFF

Sign test analyses provided interesting information about the variability of sexual characteristics in these children's voices, and emphasized the importance of studying large groups of preadolescent speakers in studies of the type being discussed here. For example, approximately 52% of these speakers were correctly identified in each of the two vowel conditions, while about 18% were consistently misidentified. It is noteworthy that about 25% of these boys and girls were identified with better than 97% accuracy in both of the vowel experiments. In short, the sexual identity of these children was as clearly defined as that seen for adult speakers. At the same time, however, about 1/3 of these children were perceptually ambiguous, meaning they were likely to be judged male or female.

Additional analyses showed that a majority of children were identically classified in the two vowel experiments, again suggesting that transfer function characteristics provided major cues about child sex. Although this was the case, about 29% of the girls and 46% of the boys were classified differently in the phonated vowel condition. For these children, it would appear that laryngeal source information did exert an influence on listeners sex judgments, although no systematic trends in listeners categorizations were noted.

With respect to the connected speech utterances, it was predicted that monotonicity would bring about a reduction in the accuracy of listener judgments. Post hoc tests on the speaker sex by utterance type interaction showed that there were significant differences between the two sentence types for both boys and girls.

SLIDE 2

As can be seen on the left portion of this slide, the rates for the male children were 72% for sentences normal and 81% for sentences monotone. In effect, listener accuracy increased by 9% when judgments were based on sentences produced in a monotonous fashion.

The right side of this slide shows the data for female speakers. In this case, the accuracy of identification increased by about 6% when perception was based on sentences containing minimal variations in fo. As can be seen, the average rate observed for the normally-intoned sentences was 69%, while for the monotonous sentences the rate decreased to 63% correct.

SLIDE OFF

Several interesting findings emerged from these data. First, monotonicity had a deleterious effect on the perception of femaleness and an enhancing effect on the perception of maleness. In other words, the presence of monotonicity increased the likelihood that a child would be assigned to the male category. This observation suggests that the perception of male vocal quality in the voices of some children may be associated with decreased variation in fundamental frequency.

It is interesting to consider the 11 children (8 females and 3 males) who underwent a shift in sexual identity as a function of the mode of sentence production. For every speaker except two, the male response rate increased when judgments were based on their monotonous sentences. Three of these speakers (2 females, 1 male) were ambiguous in the normal sentence condition, yet consistently identified male in the monotone condition. Findings such as these suggest that monotonicity is likely to elicit a male response when other cues provide ambiguous information about child sex. Interestingly, 6 other children (4 females and 2 males) categorized female in the normally-intoned sentence experiment became perceptually ambiguous in the monotone condition. In these cases, intonation patterns and perhaps other suprasegmental factors may have provided the disambiguating information. When these cues were altered, in the monotone condition, femaleness was no longer clearly defined, and the number of male judgments effectively increased because of an increase in classification errors.

Finally, the most important point to be emphasized is that the differences in listener accuracy observed between the two sentence types were less than 10% for both boys and girls, suggesting that intonation patterns did not provide primary cues to sexual identity.

The fact that 87% of the boys and 73% of the girls were identically classified in the two sentence conditions provides convincing evidence to suggest that vocal tract resonance information, and perhaps other cues as well, provided the primary information about child sex. Intonation patterns, on the other hand, were viewed to provide secondary cues, serving to further define maleness and femaleness in the voices of a majority of these preadolescent speakers.